Tests of internal-conversion theory with precise γ- and x-ray spectroscopy: the case of ^{103m}Rh studied by the ^{103}Pd electron-capture decay

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As part of our program to test internal-conversion theory through precision measurements of *K*-conversion coefficients, α_K [1], we undertook a measurement of the *E*3 decay of the ^{103m}Rh isomer, which we populated via the electron-capture decay of ^{103}Pd. Because the electron-capture decay gives rise to x rays that are indistinguishable from the x rays associated with the *E*3 decay, to extract α_K we must use a modified version of Eq. (1) in Ref. [1]:

$$\alpha_K = \frac{1}{\omega_K} \cdot \frac{N_K}{N_\gamma} \cdot \frac{\varepsilon_\gamma}{\varepsilon_K} - P_{\varepsilon,K} \cdot (1+\alpha_T) \quad (1)$$

where ω_K is the K-shell fluorescence yield, which we take from Ref. [2]; N_K and N_γ are the peak areas of the *K* x rays and γ ray, respectively; and ε_K and ε_γ are the corresponding detector efficiencies. In this particular case α_K depends on the total ICC, α_T, and on the probability for the K-shell electronic capture, $P_{\varepsilon,K}$, a quantity that can be precisely calculated.

The ^{103}Pd source was prepared by thermal neutron activation at the Triga reactor of the Texas A&M Nuclear Science Center. A foil of 99.95% chemically pure palladium from *Goodfellow,* 4 microns thick and 25 × 25 mm^2, was activated for 10 hours in a neutron flux of 7.5×10^{12} n/(cm^{2}s). The sample was then allowed to decay for about three weeks, after which we measured it intermittently for about 3.5 months, using both our well-calibrated HPGe detector, and a Si detector. A thorough impurity analysis was completed, which revealed the presence of the Rh K_α- K_β coincidence-summing peak at about 42.8 keV. The consequence of this observation is that the 39.7-keV γ-ray peak of interest must be contaminated by the Rh K_α- K_α coincidence-summing peak at about 40.2 keV, unresolved by our spectroscopic chain. Using the visible K_α K_β summing peak as a template we could correct for the invisible presence of the K_α- K_α summing peak.

There is a further complication however. Since Eq. (1) contains two unknowns, α_K and α_T, a second study of the same transition, but populated by the β^- decay of ^{103}Ru, is needed to determine both quantities independently. The ^{103}Ru-decay measurement is currently underway. In the meantime, we take α_K from calculations, and solve eq. (1) to get the total ICC, α_T. For the value of α_K we used 131.3(39), which is an average value of 135.2 if the atomic vacancy is included in the "frozen orbital" approximation and 127.4 if the vacancy is ignored, with an uncertainty covering both values. These theoretical values were obtained with the interpolator code BrIcc [1]. Our preliminary result for α_T thus becomes 1435(44).

When compared with calculations, this result shows better agreement with the "frozen orbital" calculation, which gives 1404, than it does with the calculation that ignores the atomic vacancy, which

[1] (http://bricc.anu.edu.au) of 135.2 (including vacancy, "frozen orbital" approach) and 127.4 (excluding vacancy).

gives 1389. However this result is only derived to demonstrate consistency. A really useful result awaits completion of our measurement on the β^- decay of ^{103}Ru, when the two modes of producing ^{103m}Rh can be used in conjunction to solve for both α_T and α_K.

[1] J.C. Hardy *et al*., *Progress in Research,* Cyclotron Institute, Texas A&M University (2016-2017) p. I-18.

[2] E. Schönfeld and H. Janssen, Nucl. Instrum. Methods Phys. Res. **A369,** 527 (1996).